

IRRIGATION SYSTEM WITH CORNER IRRIGATOR SPAN

RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. provisional patent application serial no. 60/423,563, filed November 4, 2002.

FIELD OF THE INVENTION

[0002] The present invention relates to an irrigation system for conveying a fluid to a region having a main boundary and an outer boundary outlying the main boundary. More specifically, the present invention relates to the irrigation system comprising a main irrigation portion for irrigating the region within the main boundary and a corner irrigator span extending from the main irrigation portion for irrigating the region between the main boundary and the outer boundary.

BACKGROUND OF THE INVENTION

[0003] Conventional irrigation systems include a series of interconnected irrigator spans having conduits for conveying fluid to a region such as an agricultural field. One such irrigation system used for this purpose is called a center pivot irrigation system. A typical center pivot irrigation system includes a center pivot tower about which the irrigator spans will rotate. The irrigator spans are connected in an end-to-end manner and extend radially from the center pivot tower. The fluid is pumped from a fluid source through the conduits of each irrigator span and is applied to the region through discharge nozzles mounted to the conduits. The irrigation system may include several irrigator spans capable of reaching tens to hundreds of acres, or the irrigation system may include only a few irrigator spans capable of reaching only a few acres. Separate drive systems rotate each of the irrigator spans about the center pivot tower.

[0004] The series of irrigator spans extending radially from the center pivot tower comprise a main irrigation portion of the irrigation system. The main irrigation portion is designed to maintain a relatively constant alignment as the main irrigation portion rotates about the center pivot tower. The main irrigation portion irrigates the region within a main boundary thereof.

[0005] A corner irrigator span extends radially from the main irrigation portion to access an outer boundary of the region thereby irrigating the region between the main boundary and the outer boundary. The corner irrigator span is capable of moving between a position in which the corner irrigator span is oriented at less than ninety degrees relative to the main irrigation portion and a position in which the corner irrigator span is in alignment with the main irrigation portion. The ability of the corner irrigator span to traverse such a wide range of positions relative to the main irrigation portion allows the corner irrigator span to flex out to reach the outer boundary of the region as the irrigation system is operating. This is particularly useful in rectangular regions in which the corner irrigator span is used to reach farther into corners of the region.

[0006] A corner drive system is used to move the corner irrigator span. The corner drive system comprises a steering unit having a steering motor for steering a set of drive wheels, and a corner drive unit having drive motors for driving the drive wheels. Typically, in the prior art, the corner drive system is responsive to a buried conductor that outlines the outer boundary of the region. A sensor is mounted on a distal end of the corner irrigator span in which the corner drive system is located. The sensor is capable of sensing the buried conductor and controlling the steering unit accordingly to ensure that the drive wheels follow the buried conductor along the outer boundary of the region. The primary downfall to such a system is the required depth of the buried conductor. Typically, the buried conductor can only be covered by less than one to two feet of earth to ensure proper operation. With such a small amount of cover, machinery such as plows, cultivators, and the like, are likely to disrupt the buried conductor, and at times, rip the buried conductor from the cover completely. In addition, the expense to place the buried conductor along the outer boundary can be high.

[0007] To improve on these irrigation systems, the prior art has attempted to engineer an irrigation system that is devoid of the buried conductor. Such an irrigation system is shown in United States Patent No. 4,340,183 to Kegel et al., granted July 20, 1982. The irrigation system of Kegel et al. includes a main irrigation portion comprising a plurality of irrigator spans connected in an end-to-end

manner and extending radially from a center pivot tower. A corner irrigator span extends radially from the main irrigation portion. Movement of the corner irrigator span is based on position data relayed to a microprocessor from a series of four encoders. The first encoder is positioned between the main irrigation portion and the corner irrigator span. The first encoder relays a control signal to the microprocessor that represents an operating angle between the main irrigation portion and the corner irrigator span. The second and third encoders are positioned on drive wheels of two adjacent irrigator spans in the main irrigation portion to determine a position of these irrigator spans relative to a reference line. The second and third encoders are responsive to the drive wheels to send a control signal to the microprocessor that represents the relative control position of the each of the respective spans to the reference line based on the movement of the drive wheels. The fourth encoder is positioned near a steering unit of the corner irrigator span to determine an angular position of the steering unit. The fourth encoder sends a control signal to the microprocessor that represents the angular position of the steering unit, i.e., the position of the drive wheels. Using the information relayed by the encoders, the microprocessor is capable of controlling the steering unit of the corner irrigator span during operation to move the corner irrigator span along the outer boundary of the region.

[0008] Although the irrigation system of the '183 patent solves the problem of using a buried conductor, other disadvantages of the irrigation system result. For instance, the second and third encoders may be subject to error based on the inconsistent motion of the drive wheels of the irrigator spans to which they are attached. The drive wheels may slip or rut. With such irregular movement and inconsistencies in the position of the main irrigation portion, difficulties arise when the irrigation system is used for fertilizer or pesticide application, or other applications that require higher precision. As a result, there is a need in the art for an irrigation system that does not rely strictly on mechanical measurements to determine control positions for the main irrigation portion.

SUMMARY OF THE INVENTION AND ADVANTAGES

[0009] The present invention provides an irrigation system for conveying a fluid to a region having a main boundary and an outer boundary outlying the main boundary. The irrigation system includes a center pivot. A main irrigation portion has a proximal end at the center pivot. The main irrigation portion extends radially to a distal end for rotation about the center pivot to irrigate the region within the main boundary. A corner irrigator span is coupled to the main irrigation portion. The corner irrigator span extends radially from the distal end of the main irrigation portion to irrigate the region between the main boundary and the outer boundary. A main drive system moves the main irrigation portion about the center pivot and along the main boundary. A corner drive system moves the corner irrigator span with the main irrigation portion and along the outer boundary. A first electrical generator operates between the corner irrigator span and the main irrigation portion to generate a first control signal representing an operating angle between the corner irrigator span and the main irrigation portion. A second electrical generator is coupled to the main irrigation portion to generate a second control signal representing a primary control position of the main irrigation portion. A controller is programmed to receive the control signals and control the corner drive system based on the control signals to maintain a target operating angle between the corner irrigator span and the main irrigation portion. The irrigation system is characterized by the second electrical generator being a position determining sensor for sensing a reference signal to determine the primary control position.

[0010] A method of controlling the irrigation system is also provided. The method of controlling the irrigation system begins by moving the main irrigation portion and the corner irrigator span about the center pivot in an operating mode. A plurality of current values for an operating angle between the main irrigation portion and the corner irrigator span are determined as the main irrigation portion and the corner irrigator span move. At the same time, a reference signal is sensed and a plurality of current values for a primary control position based on the sensed reference signal are determined. A steering unit is controlled based on the plurality of current values determined for the operating angle and the primary control position.

[0011] The present invention provides several advantages over the prior art. One advantage is the ability of the irrigation system to precisely determine the primary control position of the main irrigation portion without relying strictly on mechanical measurements. Instead, the position determining sensor senses a reference signal to determine the primary control position. By utilizing such a device, the disadvantages of mechanical measurements are alleviated. This results in better control of application rates such that the irrigation system can be used to spray chemicals such as herbicides and pesticides to the region.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Other advantages of the present invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[0013] Figure 1 is a perspective view of an irrigation system embodying the present invention;

[0014] Figure 2 is a perspective view of a main irrigation portion of the irrigation system;

[0015] Figure 2A is a perspective view of an alternative embodiment of a main irrigation portion of an irrigation system;

[0016] Figure 3 is a top view illustrating an end irrigator span and a corner irrigator span;

[0017] Figure 4 is a perspective view of a sliding joint between the end irrigator span and the corner irrigator span;

[0018] Figure 5 is a block diagram of a control system of the present invention; and

[0019] Figure 6 is a schematic view of the irrigation system of the present invention illustrating positions of the corner irrigator span and the main irrigation portion about the region.

DETAILED DESCRIPTION OF THE INVENTION

[0020] Referring to the Figures, wherein like numerals indicate like or corresponding parts throughout the several views, an irrigation system for conveying a fluid from a fluid source **12** to a region **A** is generally shown at **10**. The irrigation system **10** of the present invention can be used for a multitude of purposes. Therefore, it is to be understood that the fluid could include many different substances. The fluid could be water for irrigating crops in a field. The fluid could also be a mixture of water and chemicals for controlling pests such as insects and fungi or for controlling weeds such as grasses, thistle, ragweed, nightshade, cocklebur, and so on. The irrigation system **10** could also be used to apply fertilizers to the field. Likewise, the fluid source **12** may be a tank containing chemicals or fertilizers, a water source, and so on.

[0021] Referring to FIG. 1, a center pivot tower **13** is positioned adjacent to the fluid source **12**. A plurality of irrigator spans **14** are pivotally interconnected in an end-to-end manner from the center pivot tower **13**. The irrigator spans **14** extend radially from the center pivot tower **13**. These interconnected irrigator spans **14** constitute a main irrigation portion **16** of the irrigation system. The irrigator spans **14** rotate together in the main irrigation portion **16** about the center pivot tower **13**. A heavy-duty swivel **15** pivotally interconnects the irrigator span **14** adjacent to the center pivot tower **13** with the center pivot tower **13** to allow rotation of the main irrigation portion **16** about the center pivot tower **13**.

[0022] Referring to FIG. 2, joints **18** interconnect the irrigator spans **14** of the main irrigation portion **16**. The joints **18** may be a ball and socket type connection or a tongue and pin connection. The joints **18** are flexible to allow relative radial movement between the irrigator spans **14**.

[0023] Individual drive systems **20** move each of the irrigator spans **14** radially about the center pivot tower **13** to irrigate the region **A** within a main boundary **M** of the region **A** (see FIG. 6). Each drive system **20** comprises a drive motor **22**, a pair of gearboxes (not shown), two drive wheels **26**, and a variable frequency drive module **28** to control the speed of the drive motor **22**. A drive tower **30** supports each of the drive systems **20**. The gearboxes are positioned on opposite

sides of the drive motor 22 and are connected to the drive motor 22 by a pair of drive shafts. Each of the variable frequency drive modules 28 control the movement of the respective irrigator span 14 by varying the speed of the respective drive motor 22.

[0024] Each of the irrigator spans 14 further includes a support structure 34 and a conduit 36 supported by the support structure 34. Each of the conduits 36 is in fluid communication with each other and the fluid source 12. The fluid from the fluid source 12 travels through the conduits 36 to a plurality of discharge nozzles 38 that are spaced along the conduits 36 to spray the fluid onto the region A. A coupling 40 provides a flexible connection between each of the conduits 36 to allow vertical and radial movement of the conduits 36 relative to one another. The present invention could be practiced with any number of irrigator spans 14 extending radially from the center pivot tower 13 in the main irrigation portion 16.

[0025] Alignment mechanisms (not shown) are used to maintain alignment between the irrigator spans 14 within predetermined limits as the irrigation system 10 rotates about the center pivot tower 13. The alignment mechanisms are further described in co-pending application serial no. 09/970,564, filed October 4, 2001, herein incorporated by reference.

[0026] Referring to FIGS. 1 and 3, a corner irrigator span 42 extends radially from the last irrigator span 44 extending radially from the center pivot tower 13 in the main irrigation portion 16. Hence, the corner irrigator span 42 extends radially from the main irrigation portion 16. The last irrigator span shall be hereinafter described as an end irrigator span 44.

[0027] Referring specifically to FIG. 3, the corner irrigator span 42 has a proximal end 46 and a distal end 48. The corner irrigator span 42 further includes a corner support structure 50 (shown in FIG. 1, but not FIG. 3 for clarity) and a corner conduit 52 supported by the corner support structure 50. A plurality of discharge nozzles 53 (shown in FIG. 1, but not FIG. 3 for clarity) are spaced along the corner conduit 52 to spray the fluid from the corner conduit 52 onto the region A between the main boundary M and an outer boundary B (see FIG. 6). A corner coupling 54 flexibly interconnects the conduit 36 from the end irrigator span 44 and the corner

conduit 52. Thus, the corner conduit 52 is in fluid communication with each of the conduits 36 of the main irrigation portion 16 and the fluid source 12.

[0028] Referring to FIG. 3, a sliding joint 56 connects the proximal end 46 of the corner irrigator span 42 to the end irrigator span 44. Referring to FIG. 4, the sliding joint 56 includes a housing 58 pivotally supported on a pivot 59 mounted to the end irrigator span 44. The housing 58 defines a slot 60 for receiving the proximal end 46 of the corner irrigator span 42. More specifically, a joint member 62 fixed to the proximal end 46 of the corner irrigator span 42 moves linearly within the slot 60 relative to the housing 58 and the end irrigator span 44. This movement is indicated by the two-headed arrow. Rollers 64 are positioned on opposite sides of the joint member 62. The rollers 64 roll linearly along a base 66 of the housing 58. Hence, the corner irrigator span 42 moves linearly relative to the end irrigator span 44, as well as radially. The housing 58 includes a stop plate 68 to prevent the joint member 62 from rolling entirely through the slot 60. A reinforcement member (not shown) slidably couples the housing 58 and the corner irrigator span 42 to provide additional rigidity to the sliding joint 56 when the housing 58 pivots with the corner irrigator span 42 relative to the end irrigator span 44 about the pivot 59.

[0029] Referring back to FIG. 3, a corner drive system 70 moves the corner irrigator span 42 with the main irrigation portion 16 about the center pivot tower 13. The corner drive system 70 moves the corner irrigator span 42 along the outer boundary B as the main irrigation portion 16 moves within the main boundary M. The corner drive system 70 comprises a corner drive unit 72 and a steering unit 74.

[0030] The corner drive unit 72 comprises a pair of corner drive motors 76, each coupled to a drive wheel 78, and a corner variable frequency drive module 80 to control the speed of the corner drive motors 76. The corner drive motors 76 are mounted to a corner drive tower 82 that supports the corner drive system 70. The corner variable frequency drive module 80 controls the speed of the corner irrigator span 42 by varying the speed of the corner drive motors 76.

[0031] The steering unit 74 includes a steering motor 84 and a variable frequency drive module 89 to control the steering motor 84. The steering motor 84

pivots the drive wheels **78** to steer the corner irrigator span **42** along the outer boundary **B**. The steering motor **84** pivots the drive wheels **78** via steering linkage **88** and steering shafts **86**, as is well known to those skilled in the art.

[0032] The corner irrigator span **42** is movable through a wide range of positions relative to the end irrigator span **44** to provide better coverage to the region **A**. In other words, given a typical rectangular region **A**, the corner irrigator span **42** provides flexibility in the irrigation system to better reach the outer boundary **B** of the region **A**. The corner irrigator span **42** is intended to be oriented at an operating angle α relative to the end irrigator span **44**. See FIG. 3. Conversely, the irrigator spans **14** of the main irrigation portion **16** are intended to maintain radial alignment from the center pivot tower **13**. See FIG. 1.

[0033] Referring to FIG. 5, a control system **90** controls movement of the corner irrigator span **42**. The control system **90** comprises two separate systems to control the movement of the corner irrigator span **42**. The first system is a linear movement control system **92**. The linear movement control system **92** controls the corner drive unit **72** of the corner irrigator span **42** as the corner irrigator span **42** moves across the region **A**. The second system is a steering control system **94**. The steering control system **94** controls the steering unit **74** to steer the corner irrigator span **42** as the corner irrigator span **42** moves along the outer boundary **B**.

[0034] Referring to FIGS. 3, 4 and 5, the linear movement control system **92** includes an electrical generator **96** that is operative between the housing **58** and the joint member **62** to sense the linear movement of the joint member **62** within the housing **58**. The electrical generator **96** is preferably a rotary potentiometer **96** capable of generating a variable signal dependent upon the relative linear movement. The potentiometer **96** provides a control signal that varies as the linear movement of the joint member **62** within the housing **58** varies. The potentiometer **96** transmits the control signal to the corner variable frequency drive module **80** such that as the control signal varies, the speed of the corner drive motors **76** vary proportionally. This ensures that the corner irrigator span **42** maintains pace with the main irrigation portion **16** as both move about the center pivot tower **13** to irrigate the region **A**. Referring specifically to FIG. 4, an actuator **98** actuates the potentiometer **96**. The

actuator 98 has a first end fixed to an actuation shaft (not shown) of the potentiometer 96 to actuate the potentiometer 96. As is well known to those skilled in the art, as the actuation shaft rotates, the control signal varies. The actuator 98 has a second end slidably and rotatably coupled to the joint member 62 at the proximal end 46 of the corner irrigator span 42.

[0035] Referring to FIG. 5, the steering control system 94 includes a controller 100 having a microprocessor (not shown) and memory (not shown) for controlling the steering unit 74. The steering control system 94 utilizes control signals from four electrical generators 102,104,106,108 to control the steering unit 74. Each of the electrical generators 102,104,106,108 will be described in turn.

[0036] Referring to FIG. 3, a first electrical generator 102 is operative between the end irrigator span 44 and the corner irrigator span 42 to measure the operating angle α between the corner irrigator span 42 and the end irrigator span 44. The first electrical generator 102 provides a first control signal to the controller 100 that varies as the operating angle α between the end irrigator span 44 and the corner irrigator span 42 varies. The first electrical generator 102 may be a potentiometer, a brushless angle resolver, or other device capable of generating a variable signal dependent upon the relative angular movement of the end irrigator span 44 to the corner irrigator span 42. The first electrical generator 102 is mounted to the end irrigator span 44. A second actuator 110 actuates the first electrical generator 102 to generate the first control signal. A first end of the second actuator 110 is pivotally supported by the housing 58. See FIG. 4. A second end of the second actuator 110 is pivotally coupled to a sensing arm 111 of the first electrical generator 102. The sensing arm 111 is coupled to an actuation shaft (not shown) of the first electrical generator 102 to rotate the actuation shaft and actuate the first electrical generator 102. As is well known to those skilled in the art, as the actuation shaft rotates, the first control signal varies. In this configuration, as the housing 58 pivots about the pivot 59 with the corner irrigator span 42 and relative to the end irrigator span 44, the second actuator 110 moves the sensing arm 111 to vary the first control signal that is sent to the controller 100.

[0037] A second electrical generator **104** is coupled to the main irrigation portion **16** to generate a second control signal representing a primary control position **P** of the main irrigation portion **16**. The second electrical generator **104** is a position determining sensor **104** fixed to the end irrigator span **44**. Preferably, the position determining sensor **104** is a digital, three-axis electronic compass **104** capable of generating the second control signal representing the primary control position **P** of the main irrigation portion **16**. The electronic compass **104** uses magnetic sensors (not shown) with MR technology to sense a reference signal, e.g., the horizontal and vertical components of the earth's magnetic field, to provide position information. The electronic compass **104** is electronically gimbaled using a two-axis (pitch and roll) tilt sensor (not shown) to give accurate heading readings even when the electronic compass **104** is tilted up to forty degrees. The electronic compass **104** is reliable and rugged and does not contain any moving components. The electronic compass **104** sends the corresponding second control signal to the controller **100**. Since the electronic compass **104** is fixed relative to the end irrigator span **44**, as the end irrigator span **44** rotates about the center pivot tower **13**, the heading changes and the second control signal varies accordingly.

[0038] A third electrical generator **106** is coupled to the main irrigation portion **16** to generate a third control signal representing a secondary control position **S** of the main irrigation portion **16**. Like the second control signal, the third control signal, and hence, the secondary control position **S**, vary as the main irrigation portion **16** rotates about the center pivot tower **13**. Preferably, the third electrical generator **106** is an angle resolver **106** that measures an angle of rotation of the irrigator span **14** adjacent to the center pivot tower **13** about the center pivot tower **13**. See FIGS. 1 and 2. The angle resolver **106** is fixed to an arm **105** extending from the irrigator span **14** adjacent to the center pivot tower **13**. The angle resolver **106** is centered over a shaft **107** that defines an axis of rotation of the main irrigation portion **16** about the center pivot tower **13**. An actuation shaft (not shown) of the angle resolver **106** is coupled to the shaft **107** and both are fixed from movement relative to the main irrigation portion **16**. Hence, as the angle resolver **106** rotates with the main irrigation portion **16** and relative to the shaft **107**, the angle resolver **106** is actuated. As is well

known to those skilled in the art, as the actuation shaft rotates, the third control signal varies. The third electrical generator **106** may be a potentiometer, a brushless angle resolver, or other device capable of generating a variable control signal dependent upon the position of one of the irrigator spans **14**. In the alternative embodiment, illustrated in FIG. 2A, the third electrical generator **106** is an electronic compass **106** fixed to the irrigator span **14** adjacent to the center pivot tower **13** and identical to the electronic compass **104** on the end irrigator span **44**.

[0039] Referring back to FIG. 3, a fourth electrical generator **108** is responsive to pivoting, e.g., steering, of the drive wheels **78** by the steering unit **74** such that the fourth electrical generator **108** is capable of generating a fourth control signal that varies as the drive wheels **78** of the corner irrigator span **42** are steered in the region **A**. Hence, the fourth control signal represents a steering angle Ψ of the drive wheels **78** relative to a reference line parallel to a center axis of the corner irrigator span **42**. The fourth control signal is also transmitted to the controller **100**. The fourth electrical generator **108** may be a potentiometer, a brushless angle resolver, or other device capable of generating a variable signal dependent upon the steering angle Ψ of the drive wheels **78** of the corner irrigator span **42**. A third actuator **112**, similar to the second actuator **110**, actuates the fourth electrical generator **108**. The third actuator **112** includes a first end pivotally coupled to the steering linkage **88** and a second end coupled to an actuation shaft (not shown) of the fourth electrical generator **108** to rotate the actuation shaft and actuate the fourth electrical generator **108**. As is well known to those skilled in the art, as the actuation shaft rotates, the fourth control signal varies.

[0040] After the controller **100** receives the control signals from the electrical generators **102,104,106,108**, the controller **100** processes these control signals to ultimately control the steering unit **74**. Prior to operating the irrigation system **10** in an operating mode, however, the steering control system **94** must learn the outer boundary **B** of the region **A**. In other words, before the steering control system **94** can control the steering unit **74**, the steering control system **94** must understand where the corner irrigator span **42** is to be positioned in the region **A** during operation.

[0041] Referring to FIG. 6, the region **A** is bounded by the outer boundary **B**. The goal of the steering control system **94** is to ensure that the corner irrigator span **42** follows the outer boundary **B**. It is to be appreciated that FIG. 6 illustrates four irrigator spans **14** in the main irrigation portion **16**. A series of primary **P1-P7** and secondary **S1-S7** control positions of the main irrigation portion **16** are shown to illustrate the change in these positions **P,S** as the irrigation system rotates about the center pivot tower **13** during operation. A series of operating angles $\alpha_1-\alpha_7$ illustrate the change in the operating angle α as the corner irrigator span **42** rotates relative to the end irrigator span **44** to reach the outer boundary **B** during operation. A series of steering angles $\Psi_1-\Psi_7$ illustrate the change in the steering angle Ψ of the drive wheels **78** of the corner irrigator span **42** as the corner irrigator span **42** rotates relative to the end irrigator span **44** to reach the outer boundary **B** during operation.

[0042] Prior to operating the irrigation system, these positions **P1-P7** and **S1-S7** and angles $\alpha_1-\alpha_7$ and $\Psi_1-\Psi_7$ are programmed into the controller **100**. In other words, for each primary **P** and secondary **S** control position, there is a corresponding operating angle α , and steering angle Ψ . This teaching is performed in a teaching mode of the controller **100**. It should be appreciated that the number of positions and angles described herein is for illustrative purposes only. Furthermore, FIG. 6 only illustrates one quarter of a typical region **A**. The controller **100** would actually need to learn the positions and angles for the entire region **A**, i.e., for 360 degrees about the center pivot tower **13**. In the teaching mode, an operator manually controls the corner drive system **70** using an input device to steer the drive wheels **78** of the corner irrigator span **42** along the outer boundary **B**, while the controller **100** receives the control signals corresponding to the positions and angles to be programmed therein.

[0043] The positions and angles from the teaching mode are stored in a look-up table in the controller **100**. The controller **100** refers to the look-up table during operation of the irrigation system **10** to control the steering unit **74**. For example, with reference to FIG. 6, the look-up table may look similar to Table 1 below.

TABLE 1

Primary Control Position P1-P7	Secondary Control Position S1-S7	Operating Angle $\alpha_1-\alpha_7$	Steering Angle $\Psi_1-\Psi_7$
276°	277°	95°	10°
286°	287°	125°	35°
296°	297°	145°	55°
306°	307°	175°	80°
316°	317°	155°	60°
326°	327°	145°	40°
336°	337°	120°	15°

[0044] In the preferred embodiment, the control signals from the electrical generators **102,104,106,108** are relayed to the controller **100** every tenth of a degree while in the teaching mode. Therefore, since the irrigation system **10** revolves three hundred sixty degrees about the center pivot tower **13**, thirty-six hundred positions and angles are recorded.

[0045] Once the controller **100** has generated the look-up table in the teaching mode, the controller **100** is ready to automatically control the steering unit **74** as the irrigation system moves across the region **A** in the operating mode using the data in the look-up table.

[0046] Operation of the irrigation system **10** in the operating mode will now be described. A pacing speed of the drive motor **22** of the end irrigator span **44** is adjusted at a main control panel (not shown) to a user-defined rate. Accordingly, the drive system **20** of the end irrigator span **44** paces the irrigation system **10**. In a first series of steps, the controller **100** receives the control signals from the electronic compass **104** and the third electrical generator **106**. The controller **100** then determines current values of the primary **P** and secondary **S** control positions. These current values are then averaged. The average value is then compared to an average of the initial values in the look-up table. The average values are used to compensate for curl of the main irrigation portion **16**, as illustrated by hidden lines in FIG. 6. As shown, curling of the main irrigation portion **16** can have a dramatic effect on

positioning of the corner irrigator span **42**. This effect is reduced by averaging the primary **P** and secondary **S** control positions.

[0047] In a second series of steps, using the first row of Table 1 for illustration, a target operating angle α_1 and target steering position Ψ_1 corresponding to the average of the current values of the control positions **P,S** is retrieved from the look-up table. The controller **100** compares the average of the current values of the control positions **P,S** to the average of the initial values of the control positions **P₁-P₇,S₁-S₇** in the look-up table and retrieves the target operating angle α_1 and target steering angle Ψ_1 corresponding to the closest average of the initial values of the control positions **P₁,S₁**.

[0048] With the target operating angle α_1 and target steering angle Ψ_1 from the look-up table, the controller **100** performs a third series of steps. In the third series of steps, the controller **100** controls the steering unit **74** to ensure that the corner irrigator span **42** follows the outer boundary **B**. In the third series of steps, the controller **100** first receives the first control signal from the first electrical generator **102** and converts the control signal into a current value of the operating angle α . The controller **100** then determines if the current value of the operating angle α is equal to the target operating angle α_1 . If so, then no adjustment needs to be made, i.e., the corner irrigator span **42** is at the target operating angle.

[0049] If the current value of the operating angle α is not equal to the target operating angle α_1 , then adjustment of the drive wheels **78** via the steering unit **74** must be made to bring the corner irrigator span **42** into correct position. To start, the controller **100** determines whether the current value of the operating angle α is greater than or less than the target operating angle α_1 . In either case, the next step is for the controller **100** to determine a deviation from the target operating angle α_1 based on the difference between the current value of the operating angle α and the target operating angle α_1 . Next, the controller **100** instructs, i.e., sends an output signal to, the steering unit **74** to turn the drive wheels **78** either clockwise or counterclockwise, depending on whether the current value of the operating angle α is greater than or less than the target operating angle α_1 . The amount that the drive

wheels 78 are turned depends on the deviation. A scaled parameter, based on the deviation, is used to vary the amount that the drive wheels 78 are turned. The steering unit 74 then turns the drive wheels 78 to change a current value of the steering angle Ψ accordingly until the current value of the operating angle α is equal to the target operating angle α_1 , then the steering unit 74 returns the drive wheels 78 to the target steering angle Ψ_1 . The first, second, and third series of steps are continuously repeated to ensure that the corner irrigator span 42 follows along the outer boundary B.

[0050] The input and output signals used to control the corner drive unit 72 and the steering unit 74 are illustrated by signal lines with arrowheads in FIG. 3 and FIG. 5.

[0051] In the preferred embodiment, the irrigator spans, the support structures, the drive towers, and the conduits are made from galvanized steel. Any suitable material may be used, such as, but not limited to painted steel, iron, aluminum, and so on. The couplings are made from a rubber polymer, but may be made from any number of materials creating a flexible connection such as, but not limited to, thermoplastic polymers, flexible plastics, and so on. The motors are reversible, variable speed, AC motors. The connections between the electrical generators and power sources and electrical service such as that between the motors and variable frequency drive modules are not shown in the FIGS. for clarity, but are well understood by those skilled in the art.

[0052] Obviously, many modifications and variations of the present invention are possible in light of the above teachings. The invention may be practiced otherwise than as specifically described within the scope of the appended claims, wherein that which is prior art is antecedent to the novelty set forth in the "characterized by" clause. The novelty is meant to be particularly and distinctly recited in the "characterized by" clause whereas the antecedent recitations merely set forth the old and well-known combination in which the invention resides. These antecedent recitations should be interpreted to cover any combination in which the incentive novelty exercises its utility. In addition, the reference numerals in the claims are merely for convenience and are not to be read in any way as limiting.